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Trade Protection Comes to Silicon Valley

by Arthur Denzau

Center for the
Study of
American Business

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Highlights

Soaring prices for computer memory chips have helped fan a raging debate over the effects of U.S. efforts to protect the semiconductor industry. This study attempts to answer two primary questions about the impact of trade protection on Silicon Valley:

1. What are the high-tech employment effects of increased memory chip prices?
2. What are the market effects on integrated circuit (IC) producers and users?

While it is impossible to isolate the effects of the 1986 U.S.-Japan Semiconductor Arrangement on memory chip prices from a variety of other market factors, it is possible to compare employment effects of higher chip prices on IC firms and on computer firms using memory chips. It appears that any added jobs at the chip producers are offset by reduced employment in the chip-using companies. Silicon Valley's gains are lost elsewhere in the economy.

As for long-term market implications, semiconductor trade protection has little to commend it. Indeed, the 1986 Arrangement may well have accelerated Japanese and other Asian competitors' entry into sophisticated and highly-profitable integrated circuit applications previously dominated by U.S. firms.

A Chronology of Semiconductor Trade Protection

In July 1986, the U.S. Trade Representative's office and the government of Japan agreed to an arrangement to deal with "unfair" Japanese trade practices. American producers of memory chips were, for the first time, incurring severe losses (about $2 billion for 1985 and 1986 combined), which they attributed to the dumping of Japanese integrated circuits (ICs) on the U.S. market. Further, U.S. IC firms claimed that the Japanese market was closed to their products in spite of lower prices and other advantages.

In the dumping complaint, the basic products involved were Dynamic Random Access Memory ICs (DRAMs), which are the memory components

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in all computers. This is the largest part of the market for ICs. The annual worldwide market for memory chips is approximately $7 billion (out of a $32 billion semiconductor market). This market was pioneered in the late 1960s and early 1970s by American IC firms. During the late 1970s, Japanese companies gradually became dominant as they invested heavily in plant and equipment and increased their R&D investments while American firms cut back during economic downturns.

Today, the Japanese dominate the "merchant" market for DRAM memory chips. Merchant firms sell chips to other firms, as opposed to captive producers, such as IBM, which only produce for internal consumption. In the production of 256K chips (a quarter million memory bits on a single IC), the Japanese have a 65 percent market share, and they have captured 98 percent of the 1 megabit (1 million bits) market. Only Texas Instruments of Dallas and Micron Technology of Boise, Idaho, currently produce DRAMs for the U.S. merchant market.

The 1986 U.S.-Japan Semiconductor Arrangement was designed to stop the alleged dumping of DRAMs in the United States and other countries. The idea was to halt the "gray market" transhipment of chips to third countries which would then resell them to the United States. To monitor the pact, the Japanese Ministry of International Trade and Industry (MITI) was to gather data each quarter on transaction prices by firms as well as accounting data on costs. The Japanese firms were to charge prices on all sales sufficient to cover historical costs plus an 8 percent profit.

In addition, the Arrangement also provided for opening Japanese markets. The precise wording was that the Japanese government should provide "substantially improved opportunities for foreign semiconductor sales in the Japanese market more reflective of the competitiveness of the U.S. industry." The 1986 foreign market share in Japan was 10.3 percent, with most of this American. The agreement was expected to increase the American share to 20 percent. By the second quarter of 1987, the foreign share had risen to 12.6 percent, according to MITI, but fell to 12.3 percent by November 1987.

The initial actions taken by MITI had an immediate effect on the price of DRAMs in the United States. Within a month, it was reported that spot-market prices of 256K chips had doubled. The American IC firms could apparently take some satisfaction in this result. However, because of the 114 percent increase in Japanese IC sales to other Asian countries in 1986, there were complaints of chips being sold in the gray market. Many of these chips were ending up in the United States, either in assembled products or simply transhipped.

In March 1987, the Reagan Administration announced a new means of assuring Japanese compliance with the terms of the Arrangement. Tariffs of 100 percent of value were imposed on several categories of Japanese electronic goods produced by firms closely tied to IC producers. A total of $300 million a year in new tariffs were imposed, with the aim of forcing open the Japanese markets and halting sales of lower-priced chips to third countries.

The Bad News About the 1986 Arrangement

An anticipated and realized effect of the agreement was an increase in the U.S. price of DRAMs and the other ICs to which it applied. Higher prices are obviously beneficial for domestic IC firms and have improved their profitability. Since the Arrangement, the price of 256K DRAMs has increased from about $2.00 to over $7.00 a chip. As will be discussed below, the Arrangement is not the only reason for this price increase, but it is a major contributor.

Employment Effects

Relatively few American firms are still producing DRAMs for the merchant sector. Most left the market in the early 1980s when the Japanese decreased prices faster than U.S. firms could reduce their costs. The financial losses were so large that most producers either went out of business or merged with other firms, leaving just two U.S. companies producing DRAMs for the competitive market.

In any case, as the industry shifted from 64K to 256K to 1 megabit chips, American IC firms were less and less willing to make the investments in R&D and manufacturing facilities necessary to compete. With so few firms, employing only about 13,000 people, in DRAM production, the benefits of raising prices and increasing employment are relatively small for the U.S. economy.

While the upside of higher IC prices is not very significant, the same cannot be said about the downside. In the United States, most DRAMs are used by computer firms, both in large mainframe computers and in desktop personal computers. These memory chip users now have higher costs and are less able to compete with their foreign rivals.

The higher price of memory has important negative employment effects on downstream industries. This result is similar to my findings regarding export restraint effects in steel and steel-using industries. According to my calculations, roughly one job is lost in the electronics industry for each job saved in the semiconductor industry—hardly an effective "jobs program."

These preliminary findings reflect the *actual* price increase in memories that has occurred in the past 18 months. The typical learning curve result in the industry would imply that prices of products still being regularly produced from new designs should fall about 28 percent a year. The actual experience, gathered from both press reports and telephone conversations with knowledgeable sources in the industry, is that prices for 256K memories have more than doubled and one megabit chips have risen in price about 70 percent since the arrangement with Japan went into effect. Assuming that 70 percent of U.S. DRAM production is 256K, 10 percent one megabit, and 20 percent smaller chips, the weighted average price change is approximately 77 percent.

What are the employment benefits of the DRAM price increase? I chose two hypothetical values, 0.5 and 1.0, as reasonable estimates of medium and longer-term responses of supply to price changes. I used both estimates in my calculations in order to determine the sensitivity of employment effects to this assumption. For a 77 percent increase in price, a 0.5 percent supply increase per one percent price increase (a supply "elasticity" of .5) would mean 5,000 more jobs in DRAM production. Using a 1.0 elasticity (a one-for-one percentage increase in supply in response to a price rise) would result in added employment of 10,000. These are the basic benefits of the price increase in terms of jobs.

To calculate job losses in industries using memory chips, we need to determine the effects of memory price changes on costs of downstream products and then calculate the resultant change in demand due to higher prices for these products. To simplify the task, I ignored all uses of DRAMs other than computer applications.

Employment increases of 5,000 to 10,000 jobs are estimated at the two DRAM-producing companies. In the DRAM-using companies, however, between 7,000 and 11,000 jobs are likely to have been lost.

To analyze the computer industry's use of DRAMs, I estimated the portion of a computer's cost attributable to DRAMs from a bill of goods for building the computer. (See Appendix.) Given the memory cost share and memory price increase, I was able to calculate the cost increase for each category (sales price level) of computer. Assuming a one percent loss in demand for each one percent increase in price, 1986 shipments fell by $1.2 billion or 2.6 percent. If employment is proportional to output (i.e., a one percent drop in output implies a one percent decrease in employment) the computer industry lost 7,000 jobs due to higher memory chip prices in 1986. The net result would be roughly 2,000 fewer jobs overall if the demand for memory chips increases a half percent for each one percent DRAM price increase, or a net gain of 3,000 jobs if DRAM supply increases on a one-for-one basis with price rises.

A more sophisticated analysis of demand responses in the computer industry to memory chip price increases yields a less rosy scenario. Taking into account differential levels of foreign competition in different value segments of the industry, I estimate a loss of 11,300 jobs in the computer industry. Thus, the net employment effects are 6,400 and 1,400 jobs *lost* for memory chip supply elasticities of .5 and 1.0, respectively. Qualitatively, the results are not much different from those derived from the simpler analysis—job losses in computers more than offset gains in semiconductor employment (see Table 1).

Not all the calculated price increase is actually a result of the 1986 Arrangement, however. First of all, yield problems (subpar learning curve

yield improvements) with one megabit chips have slowed the redesign of old boards using 256K chips, and kept computer firms from scrapping old designs. In addition, Japanese IC firms may have reduced 256K capacity earlier than planned because of the Semiconductor Arrangement. Press

Table 1

EFFECT OF THE 77 PERCENT DRAM PRICE INCREASE ON IC AND COMPUTER INDUSTRY EMPLOYMENT
(Using 1986 Employment and Shipment Figures)

Semiconductor (IC) Industry: (Total Employment 12,880)	
Job Gains/<Losses> Assuming:	
0.5 Supply Elasticity*	5,000
1.0 Supply Elasticity	9,900
Computer Industry: (Total Employment 400,800)	
Job Gains/<Losses> Assuming:	
Constant (-1.0) demand elasticity for all computer value categories	<6,900>
Variable demand elasticities (-1.0 to -3.0)	<11,300>

Net Manufacturing Job Gains/<Losses>:

	Supply Elasticity	
	0.5	1.0
Constant -1.0 demand elasticity	<1,900>	3,000
Variable demand elasticities (-1.0 to -3.0)	<6,400>	<1,400>

*Supply elasticity is the ratio of the percent change in supply induced by a one percent change in price. Demand elasticity is similarly defined.

Source: Center for the Study of American Business.

reports in spring 1987 indicate that MITI persuaded the Japanese IC firms to reduce DRAM production. The firms may have used the opportunity to retool for the newer one megabit chips. The lower-than-anticipated yields for the one megabit chips have reduced the benefits of this transition, however, and the reduced supply of 256K chips has pushed up prices.

Lastly, demand has increased more than expected. The announcement last year by IBM of its PS/2 line of personal computers (some of which can use megabit chips), the competitive responses by PC-compatible firms, Apple's success with the Macintosh line, and the dramatic explosion of the engineering workstation market have generated increases in demand for large memory chips beyond previous expectations.

Together, these factors would have caused DRAM prices to fall less than the normal 28 percent a year. Exactly how much of the actual cost increases is attributable to these factors rather than the 1986 Arrangement is not easy to disentangle. However, the size of the price increase is not itself the issue for the purpose of comparing job gains and losses. If, for example, only a quarter of the 77 percent average price increase were attributable to the 1986 Arrangement, the ratio of job gains and losses would be the same, simply scaled down by a factor of four.

Of these sources of increased price, the most important is likely the one megabit yield problems. With parts produced in volume, yields normally improve as more experience is gained in production (one of the most important single sources of learning curve economies, along with redesigns). This lack of anticipated improvement has created a very tight supply situation, so that the Japanese IC firms are being paid market prices above the minimum prices specified by the cost determination accounting system created under the Arrangement.

Other Harmful Side Effects

The longer-run implications of the semiconductor agreement are even more important than the immediate problems created during the current DRAM shortage. The pact creates lower relative costs for the Japanese electronics firms that make computers. The Arrangement raised the price of DRAMs to American computer firms, but could not directly affect the real cost of chips to the computer subsidiaries of the Japanese IC firms. These Japanese computer firms buy at "transfer prices" which can be set at whatever level required to make MITI and the American government happy. Since the same investors own both the IC firm selling the chips and the computer firm buying the chips (most stock of all firms in a Japanese *keiretsu* is held by the other firms in it), it does not matter what transfer price is reported to MITI—that price only determines which firm reports the profit. Thus, the Japanese computer firms have been primed to compete more effectively with the United States in the memory-hungry mid-size mainframe and workstation markets.

This situation is quite advantageous for the vertically-integrated com-

puter firms. Even though the firms are sacrificing the opportunity to sell DRAMs at the elevated market price when they transfer-price the circuits to the computer manufacturing division, there is an important strategic benefit obtained by doing so. Under current conditions, American makers of computers and of some computer peripheral equipment are being forced to cancel production or postpone introduction of products because of inadequate supplies of memory circuits. U.S. firms have become not merely higher-cost suppliers, but also unreliable suppliers. A Japanese firm can commit to a delivery date and actually meet that schedule by virtue of its secure flow of DRAMs from its associated IC firm. The longer-run competitive effects of such problems may be substantial as the Japanese computer firms develop a reputation as the most reliable source.

Because of inadequate supplies of memory circuits, U.S. firms have become not merely higher-cost suppliers, but also unreliable suppliers.

Interestingly enough, the original enforcement of the DRAM pricing provisions of the Arrangement were less advantageous for Japanese firms. MITI used its power to withhold export licenses to force the Japanese IC firms to cut production of DRAM chips by 34 percent in early 1987. As mentioned previously, the firms were willing to cut production at that time in order to retool for production of one megabit chips. The reduced output did increase the price of DRAM chips to Japanese computer affiliates, and reduced the memory price advantage they would have had if they had continued to produce higher volumes of 256K chips. However, due to pressure from the U.S. Department of Commerce and the U.S. Semiconductor Industry Association, the cutbacks were abandoned in November 1987.

The Arrangement does help American DRAM producers—all two of them—but these benefits are coming at the expense of American computer firms. In addition to Japanese competition, the Koreans are rapidly acquiring the capacity to produce their own DRAMs for use in the personal computers they ship to the United States. Even if the Japan-United States Arrangement convinces the Korean IC firms to refrain from "dumping" cheap DRAMs into the United States, they can still improve the competitiveness of their computers by increasing memory chip production.

Added Perspective on Integrated Circuit Economics

Learning Curve Pricing

The original complaint by the IC industry that generated the Arrangement was that Japanese firms were dumping ICs in America, at prices below their cost of production or their sale prices in Japan. When considering the dumping issue, we should remember that we are examining an

industry in which learning curve economies are important—products are continually getting cheaper to produce. It is standard practice for firms to price bids such that the contract will make a profit *if* they can continue to cut their costs between the time of getting the order and actually producing the product. This is called "learning curve pricing." With normal cost reductions of 28 percent a year and three- to eight-month lead times on orders, a firm can bid 5 percent to 15 percent below current costs and still expect to make money on the order.

Thus, to say that the Japanese were selling DRAMs at prices below their cost of production is to say that they were doing the same thing that American firms do. This duplicity calls to mind the Will Rogers observation, "If the other fellow sells cheaper than you, it is called 'dumping'! Course, if you sell cheaper than him, that's 'mass production.'" This action may be illegal for the Japanese under American trade laws, but it is precisely the same marketing strategy employed by the complaining American firms.

If the Japanese carried out the 1986 arrangement to the letter, this would continue to keep American DRAM prices above Japanese learning curve pricing levels, so long as the dollar/yen exchange rate does not keep falling. The mechanism for setting Japanese prices is interesting—possibly inscrutable. Their firms submit accounting cost data each quarter to MITI, which then determines their historical cost per part. From the middle of a quarter, MITI requires at least three months to gather the data and certify a new price. This price is then in place for the new quarter. Altogether, this means that Japanese prices based on costs are four to six months back up the learning curve. With current yield problems, the differential may be less than 3 percent, but it would ordinarily be 10 percent. Such a cost disadvantage could be critical to American manufacturers of small computers, as the memory share of the production costs for those products is over 10 percent.

Handicapping one of our most successful industries (computers) and ignoring the benefits of an international division of labor seems a foolish step unless there are major offsetting benefits—and these are hard to find.

The precedent established by the Arrangement is also very important. Potentially, a similar arrangement might be applied to future generations of DRAM parts, the 4 and 16 megabit parts and other future families of ICs. American computer firms and other electronics companies will be forced to compete in a market environment where the vertically-integrated Japanese firms will benefit from learning curve economies, while U.S. firms must rely on potentially higher-cost American suppliers, protected for 4 to 6 months from Japanese learning curve pricing effects. Handicapping one of our most successful industries (computers) and ignoring the benefits of an international division of labor seems a foolish step unless there are major offsetting benefits—and these are hard to find.

The 1987 Tariffs

Good news about tariffs is a rare commodity. But the tariffs of 1987 were carefully crafted to avoid major negative side effects on American firms and did get the Japanese to greatly reduce gray market sales of DRAMs.

In particular, the 1987 tariffs on Japanese electronics firms did not harm U.S. firms using Japanese ICs as much as would have been the case if ICs had been directly controlled. This is an important point. In a 1987 report for the Center for the Study of American Business, I found that quotas or tariffs on an intermediate good such as steel (or in this case semiconductors) can adversely affect firms using the products. In the case of the 1984 steel voluntary export restraints, job losses among the using firms outnumbered steel worker jobs saved by a factor of 3 to 1.

The 1987 electronics tariff imposed on Japan only applied to final consumption goods directly purchased by American consumers. There were no downstream industrial users of the taxed goods, and thus minimal job losses in American manufacturing resulted.

While there still might have been employment losses in wholesale and retail trade, the second feature of the tariff also mitigated this effect. The goods to be taxed were chosen precisely because there were non-Japanese sources of supply, typically Korean, Taiwanese or domestic. This helped to minimize the price rises felt by consumers and the disruptive effects on the channels of distribution. While individual firms might have been hurt, the overall effects on wholesale and retail trade should have been slight, with gainers just about equal to losers.

But why should such a tariff on Japanese electronics help encourage the Japanese IC firms to abide by the 1986 agreement? The third feature of the tariff provides part of the answer: The goods of only five Japanese electronics firms were to be taxed. These firms were either parent companies or tied very closely through mutual stock ownership to the IC firms which were supposed to carry out the Semiconductor Arrangement. The vertical integration of the Japanese industry, with a firm such as Hitachi starting with silicon and producing most of the value added in a TV set, enabled the American government to use restrictions on the final goods market to enforce the semiconductor agreement.

Getting the Japanese to live up to their bargains may be an admirable goal *per se*; however, the key issue is the effectiveness of the original 1986 Arrangement itself. Before one speaks too admiringly of the spit and polish put into preparing the gallows for its work, one should be certain of the appropriateness of the sentence being carried out.

What is Lost if U.S. Firms Do Not Make DRAMs?

What is the cost to our economy if most U.S. IC firms do not make DRAMs? These are the largest volume parts produced by the Japanese, and seem to provide the greatest learning curve benefits to firms that make them. If this is true, then it would certainly make great economic sense to make DRAMs "loss leaders" and push total production of them as rapidly as possible..

Supporting these cost factors are some key marketing principles. From auto manufacturers to computer firms, purchasing departments have been reducing the number of vendors with whom they deal, along with increasing the average volume of business with each. For some semiconductor users, the reduction has been very large, from as many as 300 vendors down to 10. To remain one of this much smaller number of suppliers, a semiconductor company will often be expected to be a full-line supplier. Thus, being able to supply DRAMs makes it more likely that customers will buy the full range of semiconductor needs from a given firm. At present, this competitive edge goes to the Japanese IC firms.

If these marketing factors were salient considerations, however, it would be hard to understand why American firms abandoned the DRAM business in the first place. Therefore, there must be important countervailing considerations. While there may be substantial cost economies in pushing hard to move down the learning curve, there also are substantial risks to doing so. Further, the transfer of learning curve experiences from DRAM production to other IC products may be considerably less than might be anticipated.

The chief financial risk involved in pursuing the high volume strategy is inherent in its physical embodiment, the focused factory. In the past five years, factories have been built, initially in Japan but now also in the United States, that build only one or two different integrated circuits. Large IC firms can have several focused factories producing large volumes of parts such as DRAMs, but most medium-size firms can afford only one or two manufacturing facilities. American firms that do not produce DRAMs have few, if any, parts that are produced in sufficient volume to warrant operation of a focused factory.

The problem with focused factories is that they create an "all the eggs in one basket" situation. If a bottleneck develops in a focused factory, then all production of an important type of part stops. Small problems have the potential of causing major production stoppages.

As mentioned previously, beyond the added risk posed by operating focused factories, the application of learning curve knowledge from DRAM production to production of other circuits may prove illusory. Production economies are provided by mask design (in essence, masks are photographic templates) and wafer fabrication process improvements. While some aspects of the design problems in DRAMs apply to other complex parts, some of the basic techniques used in dealing with DRAM mask

design are of relatively little value in designing other parts.

For instance, reducing the size of the basic memory cell of a one megabit DRAM produces large benefits since there are a million of them on a single chip. The rest of a megabit DRAM consists of a smaller number of other cells that have to be designed, and improvements in size of these cells have little effect on the cost of the part. Thus the basic design problem is to reduce the size of a memory cell—other problems receive far less attention. However, reducing the size of the basic memory cell provides relatively little useful knowledge for producing the many types of cells that have to be designed for other complex ICs.

Process improvement in wafer fabrication is another source of DRAM learning curve effects that potentially could be used in many other parts. The reality is that the spillover benefits are often rather small because of the "Not Invented Here" syndrome. The use of focused factories, whether in Japan or the United States, can exacerbate the problem. The things learned within one plant may never be transmitted from that plant, and when they are, they may be viewed as less useful by the management of a sister plant.

The Japanese have been able to push the United States out of the DRAM market not only by making earlier investment in production capacity, but also by developing manufacturing skills.

If U.S. firms choose to compete with Japanese firms without using focused factories, they could realize some benefits of being full-line suppliers, but they would be producing DRAMs at substantially higher cost than Japanese firms. If these technical and marketing advantages are large enough, then this might provide a rationale for support of trade sanctions against the Japanese. But it does not mean that these sanctions are good public policy. Will Rogers once said, "If business thrives under a protective tariff, that don't mean that it has been a good thing. It may have thrived because it made the people of America pay more for the object than they should have, so a few got rich at the cost of many." This simple wisdom seems quite applicable to the Semiconductor Arrangement of 1986.

Potentially, the Arrangement could have an even more dangerous effect, depending on the Japanese response to a reduced market for DRAMs. It is a common view that the Japanese have been able to push the United States out of the DRAM market not only by making earlier investment in production capacity, but also by developing manufacturing skills. American design and software skills have been viewed as one of our comparative advantages, and this has resulted in a leadership position in application-specific integrated circuits (ASICs) and central processing units (CPUs). By reducing the benefits to Japanese firms from their manufacturing advan-

tages, we may push them even further into improving their design and software skills.

Large potential markets for the Japanese exist in the United States in ASICs and CPUs. If the Japanese are as single-minded as some American commentators have claimed, one should expect them to move into these areas. Even if we view the Japanese IC firms as merely avid competitors, the trade Arrangement has shifted the relative benefits for them of various research efforts, and we should expect competitive pressure in the profitable markets that American firms have dominated.

Summary

This study examined the effects of the 1986 U.S.-Japan Semiconductor Arrangement, which was designed to stop the alleged dumping of DRAMs in the United States and to open Japanese markets to U.S.-made semiconductors.

The accord has certainly been successful in putting a stop to underpriced memory chips—some of the most popular random access memory chips (DRAMs) have more than doubled in price due to the agreement and other market factors. These higher prices have improved the profitability of *both* domestic IC-producing firms. Since these firms employ only about 13,000 people, however, the benefits of raising prices and increasing employment are relatively small for the U.S. economy. In contrast, most DRAMs are used by the electronics industry, which employs more than 400,000 people. These memory chip users now have higher costs, and are less able to compete with their foreign rivals.

A comparison of the employment effects on the two industries shows that roughly one job is lost in the electronics industry for each job saved in the semiconductor industry. With the methodology used in this report, we can estimate employment increases of 5,000 to 10,000 jobs at the two DRAM-producing companies. In the DRAM-using companies, however, between 7,000 and 11,000 jobs are likely to have been lost.

But our greatest concern should be our long-range competitiveness. The pact creates lower relative costs for the Japanese vertically-integrated electronics firms that make both chips and computers. The extra profits from the sanctioned Japanese cartel have priced Japanese computer firms to compete more effectively with the United States in mainframe and workstation markets which have traditionally been dominated by the United States. In addition, the shortage of memory chips that has resulted, at least in part, from the trade sanctions is forcing U.S. computer manufacturers to cancel production or postpone introduction of products.

In conclusion, the combination of Japanese industrial organization and American trade protection has been a financial benefit to Japanese firms—and is now even pushing these firms into new IC markets and computer

lines that are currently dominated by the United States. It would appear to be a poor tradeoff if the United States were to recapture a small share of the DRAM market but lose ground in the rapidly-burgeoning, application-specific integrated circuit market to Asia. In short, we are in danger of sacrificing our future to regain the past.

Appendix

To determine the future impact of the Arrangement, the critical assumptions are those about supply and demand elasticities. Supply assumptions were discussed in the employment effects section of this paper. On the demand side, it is necessary to determine the effects of the memory price changes on the costs of downstream products, and then to calculate the change in demand that results from the downstream price changes. Here, all uses of DRAMs other than that in the computer industry (Standard Industrial Classification 3573) are ignored.

In earlier studies of this sort that I have undertaken, it was possible to use the Commerce Department's input-output tables to determine the importance of an intermediate good (steel, for instance) to other industries. Lacking such data here, a simpler approach was used—that of a bill of goods for building a computer. The basic question is how much of the production cost of a computer is made up of DRAMs? This can be answered by using various memory sizes for the different size computers for which shipment data are available, as shown in Table A-1. In this analysis, the price per megabit chip is assumed to be $20. The cost of each category of computer is assumed to be the midpoint of the cost of the range shown except for the lowest-priced computer range, for which $375 was used as the category cost. DRAM cost shares are about 15 percent of total costs for computers priced below $2,500, and then decline considerably.

Given the memory cost share and the memory price increase, the total price increase for each value category of computer is calculated in Table A-2. This table assumes that the demand elasticity for all computers is -1, which is a default assumption used in the absence of specific data. With this elasticity, the change in the value of shipments is shown as Annual Output Change. For example, the least-expensive category, under $500, shows an output loss of $21 million, an 11 percent drop. The price elasticity should probably be much larger, as this sector of the market is under considerable competitive pressure from Asian suppliers.

Totalling the effects, a drop in shipments of $780 million is attributable to the memory price increase, or a 1.7 percent loss on the 1986 shipments of $45.2 billion. If employment changes in proportion to the shipments, this means 6,900 fewer employees in the computer sector as of February 1987. On net, the results show a loss of 1,900 jobs if a 0.5 supply elasticity holds, or a net gain of 3,000 jobs at a 1.0 supply elasticity. (See Table 1 in the text.) Basically, the effect on the IC industry and the computer industry are of approximately the same size.

Only a slightly different picture emerges if the differential foreign competition problems in different value segments of the industry are accounted for. In Table A-3, it is assumed that the lowest value categories are under the most pressure from imports. For the first two categories, computers selling for under $1,000, a demand elasticity of -3 is assumed. For the next

two, from $1,000 to $5,000, an elasticity of -2 is used. With this more realistic approach to the demand elasticities, the results are a loss of 11,300 jobs in the computer industry offsetting the IC increases of 5,000 (0.5 supply elasticity) or 9,900 (1.0 elasticity). The net effects are now both negative, a loss of 6,400 and 1,400 jobs respectively. Qualitatively, the results are not much different from before and the basic idea that the job losses in computers fully offset the gains in semiconductors is evident.

Table A-1

MEMORY REQUIREMENTS BY VALUE OF COMPUTER

Value of Computer	Memory Size	Average Price of Computer	Memory Cost	Memory Share of Cost
Less than $500	256K	$375	$53	0.1422
$500 to $1,000	640K (3/4) 1 MEG (1/4)	750	130	0.1733
$1,000 to $2,500	1 MEG (1/2) 2 MEG (1/2)	1,750	240	0.1371
$2,500 to $5,000	1 MEG (1/4) 2 MEG (3/4)	3,750	280	0.0747
$5,000 to $15,000	2 MEG (1/2) 4 MEG (1/2)	10,000	540	0.0540
$15,000 to $50,000	2 MEG (1/4) 4 MEG (3/4)	32,500	1,260	0.0388
$50,000 to $250,000	8 MEG	150,000	1,440	0.0096
$250,000 to $1 million	12 MEG	617,100	2,160	0.0035
Greater than $1 million	16 MEG	14,400,000	2,880	0.0002

Source: Center for the Study of American Business.

Table A-2

EFFECT ON COMPUTER INDUSTRY EMPLOYMENT* OF DRAM MEMORY PRICE INCREASES SINCE 1986, ALL DEMAND ELASTICITIES SET TO -1

(All $ Figures in Millions)

Sales Price Level	1986 Sales	Memory Share	Annual Memory Use	Price Elast.	Annual Output Change	% Output Change
Less than $500	$196	0.1422	$28	-1	-$21	-11.0%
$500 to $1,000	261	0.1733	45	-1	-35	-13.3
$1,000 to $2,500	1,816	0.1371	249	-1	-192	-10.6
$2,500 to $5,000	3,394	0.0747	253	-1	-195	-5.7
$5,000 to $15,000	1,120	0.0540	60	-1	-47	-4.2
$15,000 to $50,000	2,765	0.0388	107	-1	-83	-3.0
$50,000 to $250,000	2,850	0.0096	27	-1	-21	-0.7
$250,000 to $1 million	3,206	0.0035	11	-1	-9	-0.3
Greater than $1 million	1,716	0.0002	0	-1	0	0.0
Total Computer	$17,324		$780		-$603	-3.5%
Other Uses of DRAMs						
Special Purposes—Digital	$1,834	0.0300	$55	-1	-$42	-2.3
Peripheral Equipment	16,888	0.0050	84	-1	-65	-0.4
Parts	9,179	0.0100	92	-1	-71	-0.8
Total Other Uses	$27,901		$231		-$178	-0.6%
GRAND TOTAL	$45,225		$1,011		-$781	-1.7%

*Employment Losses = 400,800 initial employment × -1.7 percent = -6,900.

Source: Center for the Study of American Business.

Table A-3

EFFECT ON COMPUTER INDUSTRY EMPLOYMENT* OF DRAM MEMORY PRICE INCREASES SINCE 1986, DEMAND ELASTICITY GREATER AT LOW COSTS

(All $ Figures in Millions)

Sales Price Level	1986 Sales	Memory Share	Annual Memory Use	Price Elast.	Annual Output Change	% Output Change
Less than $500	$196	0.1422	$28	-3	-$64	-32.9%
$500 to $1,000	261	0.1733	45	-3	-105	-40.0
$1,000 to $2,500	1,816	0.1371	249	-2	-383	-21.1
$2,500 to $5,000	3,394	0.0747	253	-2	-390	-11.5
$5,000 to $15,000	1,120	0.0540	60	-1	-47	-4.2
$15,000 to $50,000	2,765	0.0388	107	-1	-83	-3.0
$50,000 to $250,000	2,850	0.0096	27	-1	-21	-0.7
$250,000 to $1 million	3,206	0.0035	11	-1	-9	-0.3
Greater than $1 million	1,716	0.0002	0	-1	0	0.0
Total Computer	$17,324		$780		-$1,102	-6.4%
Other Uses of DRAMs						
Special Purposes—Digital	$1,834	0.0300	$55	-1	-$42	-2.3
Peripheral Equipment	16,888	0.0050	84	-1	-65	-0.4
Parts	9,179	0.0100	92	-1	-71	-0.8
Total Other Uses	$27,901		$231		-$178	-0.6%
GRAND TOTAL	$45,225		$1,011		-$1,280	-2.8%

*Employment Losses = 400,800 initial employment × -2.8 percent = -11,300.

Source: Center for the Study of American Business.

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